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Zang et al.

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(45) **Date of Patent: Feb. 23, 2021**

(54) **DETECTING HARD-CODED STRINGS IN SOURCE CODE**

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G06F 21/56 (2013.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06F 11/3664*** (2013.01); ***G06F 8/427*** (2013.01); ***G06F 8/75*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ... G06F 8/53; G06F 8/427; G06F 8/33; G06F 8/75; G06F 21/565; G06F 21/562;
(Continued)

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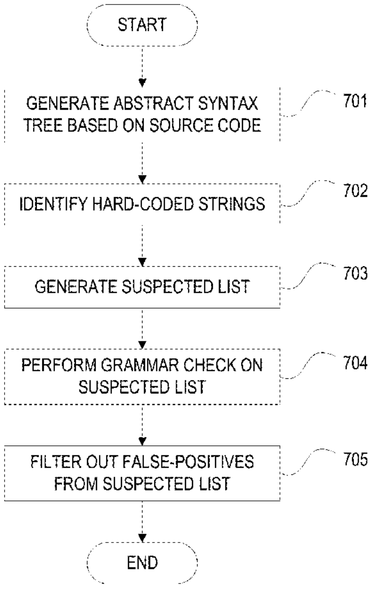
Primary Examiner — Anibal Rivera

(57) **ABSTRACT**

Methods and systems for detecting hard-coded strings in source code are described herein. According to an aspect of an example method, a first list of strings may be generated via a processor. The first list of strings may include strings that are embedded in source code of an application. A second list of strings may be generated. The second list of strings may include strings that are rendered via a user interface of the application. Each string of the first list of strings may be compared against the strings of the second list of strings. Based on the comparison, a filtered list of strings may be generated by removing, from the first of strings, at least one string that does not have a match in the second list of strings. By this method, the software development process, and especially updating, maintaining, and localizing code, may become more efficient and cost-effective.

20 Claims, 10 Drawing Sheets


START
GENERATE ABSTRACT SYNTAX TREE BASED ON SOURCE CODE
701
IDENTIFY HARD-CODED STRINGS
702
GENERATE SUSPECTED LIST
703
PERFORM GRAMMAR CHECK ON SUSPECTED LIST
704
FILTER OUT FALSE-POSITIVES FROM SUSPECTED LIST
705
END

(51) **Int. Cl.**

G06F 9/448	(2018.01)
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G06F 8/75	(2018.01)
G06F 8/41	(2018.01)
G06F 8/53	(2018.01)
G06F 16/951	(2019.01)
G06F 16/901	(2019.01)
G06F 8/33	(2018.01)

(52) **U.S. Cl.**
CPC *G06F 8/33* (2013.01); *G06F 8/53* (2013.01); *G06F 11/3604* (2013.01); *G06F 11/3608* (2013.01); *G06F 16/901* (2019.01); *G06F 16/951* (2019.01)

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CPC G06F 21/54; G06F 21/52; G06F 9/454; G06F 16/90344; G06F 16/90; G06F 16/901; G06F 16/835; G06F 16/35; G06F 16/3322; G06F 16/951; G06F 16/258; G06F 16/221; G06F 11/3604; G06F 11/3608; G06F 11/36; G06F 11/3664; G06F 21/577; G06F 21/22; G06F 9/44589
See application file for complete search history.

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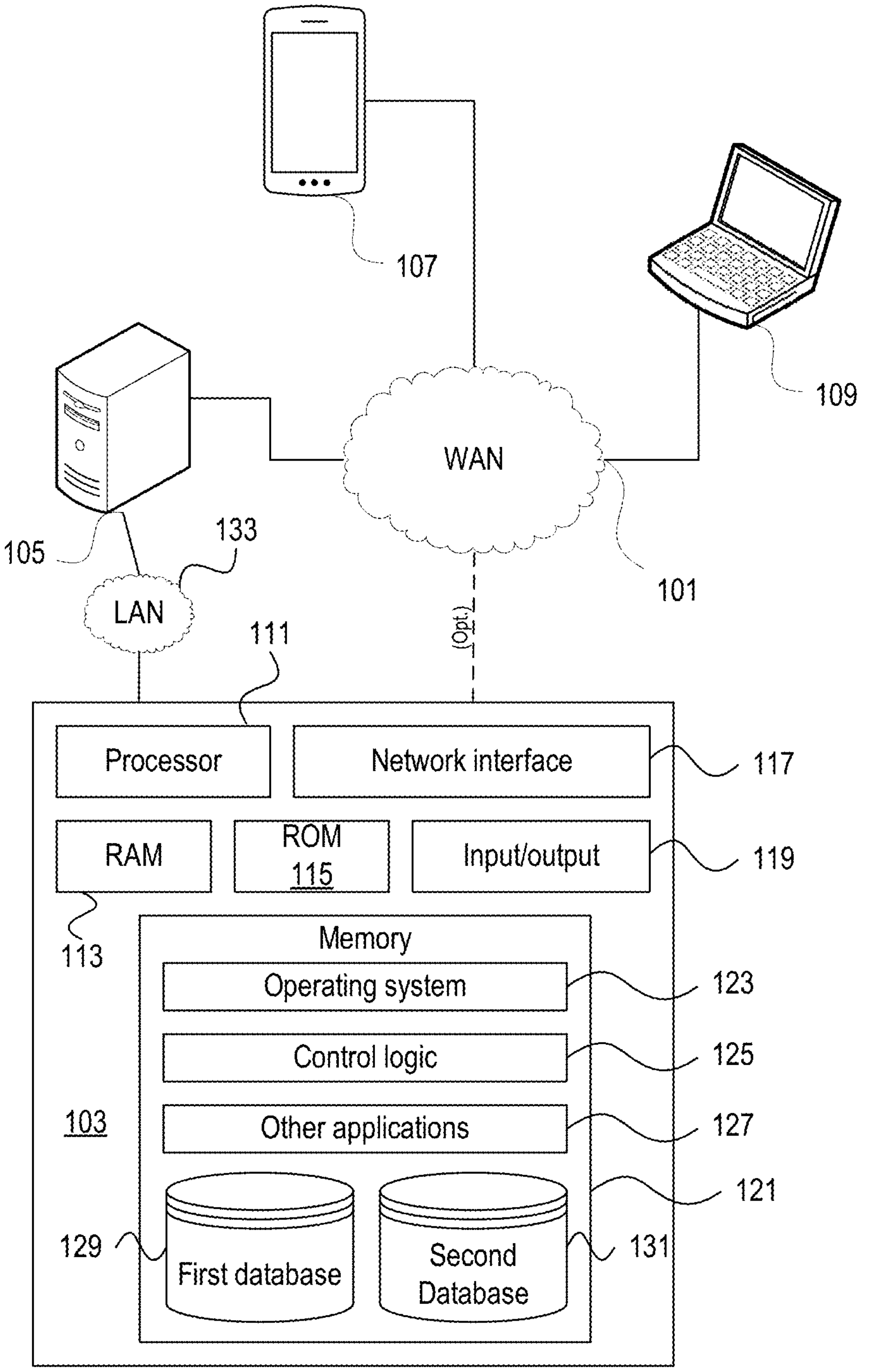


107
109
WAN
105
133
101
LAN
111
(Opt.)
Processor
Network interface
117
RAM
ROM
115
Input/output
119
113
Memory
Operating system
123
Control logic
125
103
Other applications
127
121
129
First database
Second Database
131

FIG. 1

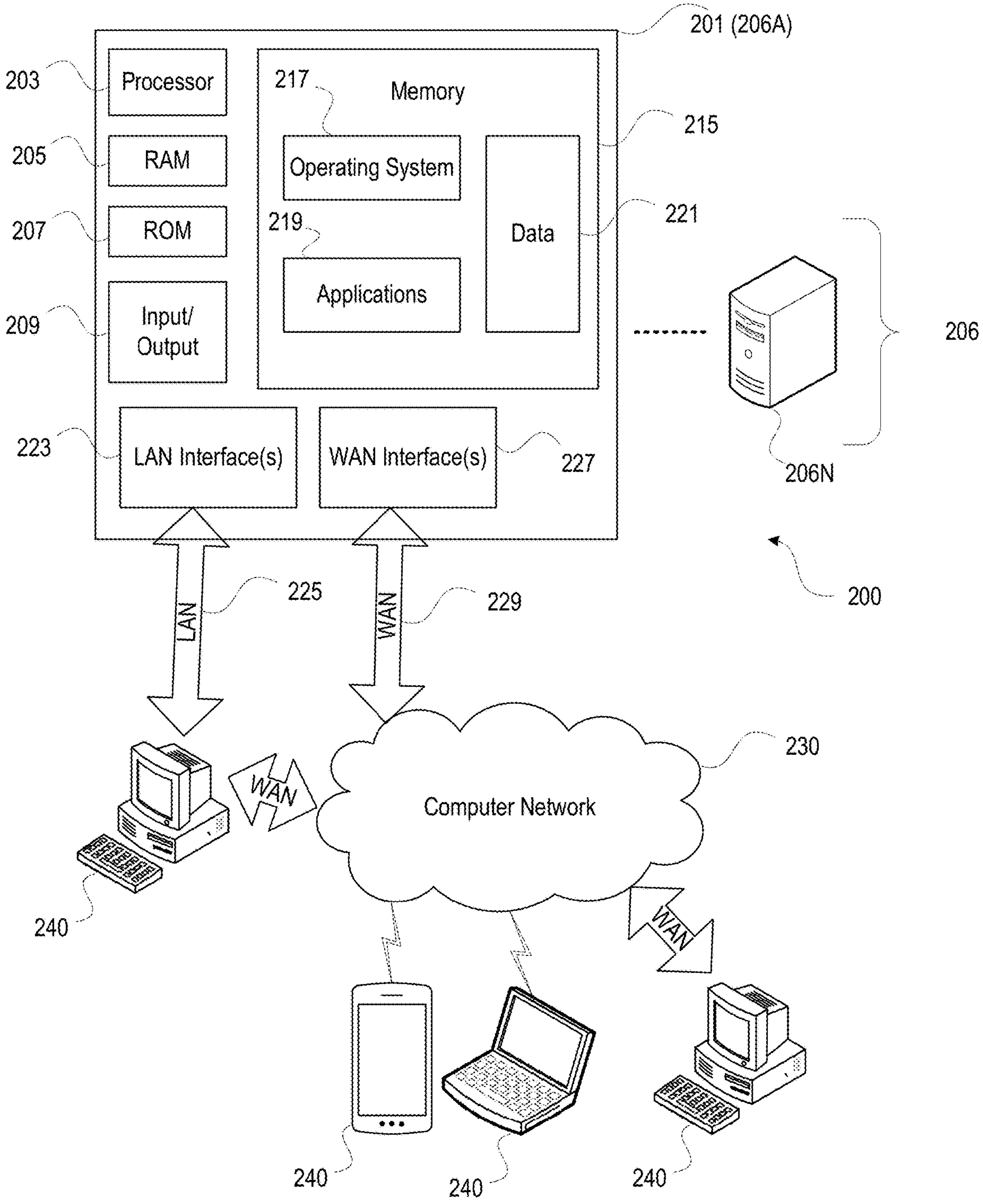

201 (206A)
203
Processor
205
RAM
207
ROM
209
Input/ Output
217
Memory
Operating System
219
Applications
Data
215
221
206
206N
223
LAN Interface(s)
WAN Interface(s)
227
LAN
225
WAN
229
200
230
Computer Network
WAN
WAN
240
240
240
240

FIG. 2

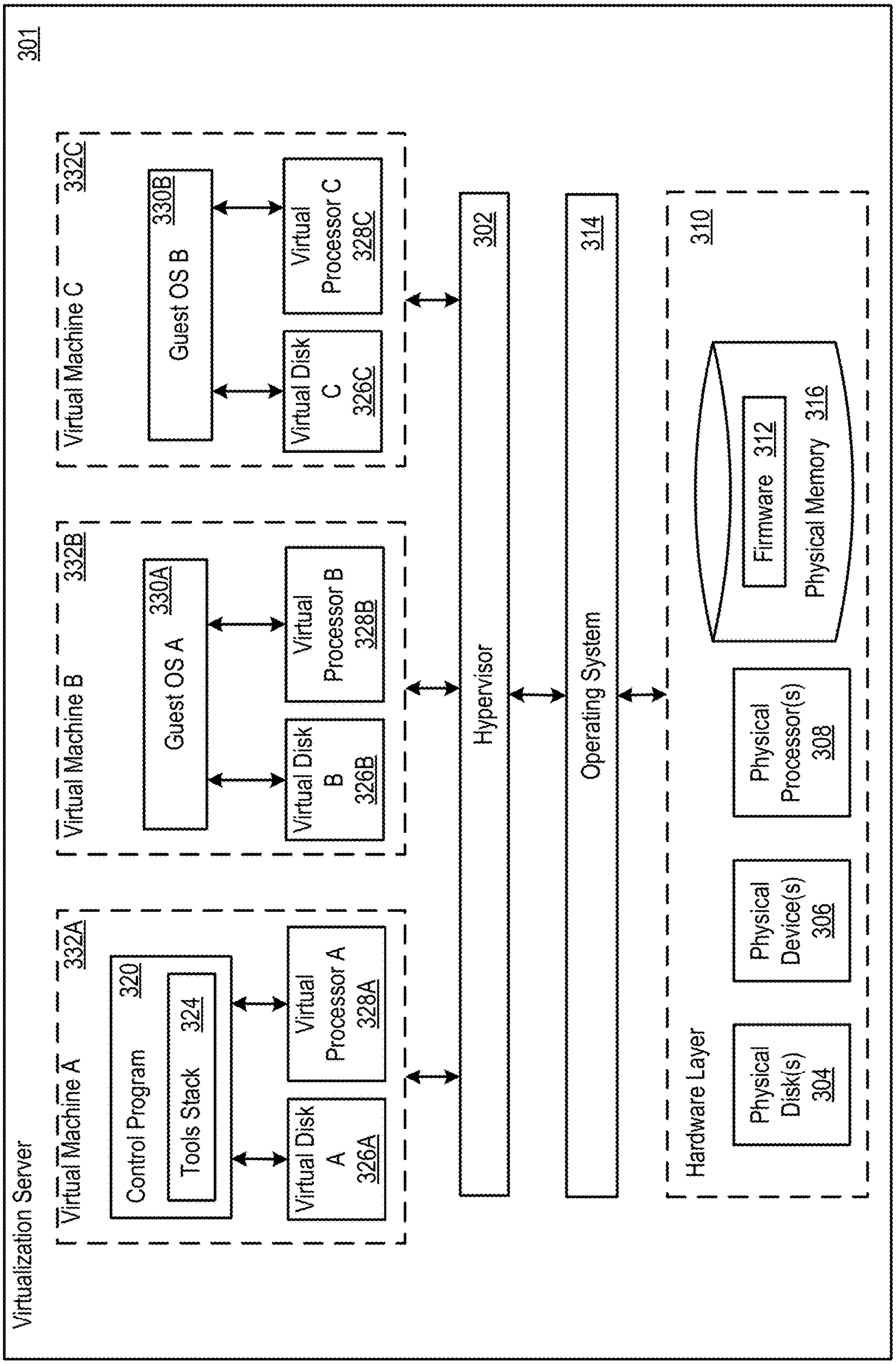
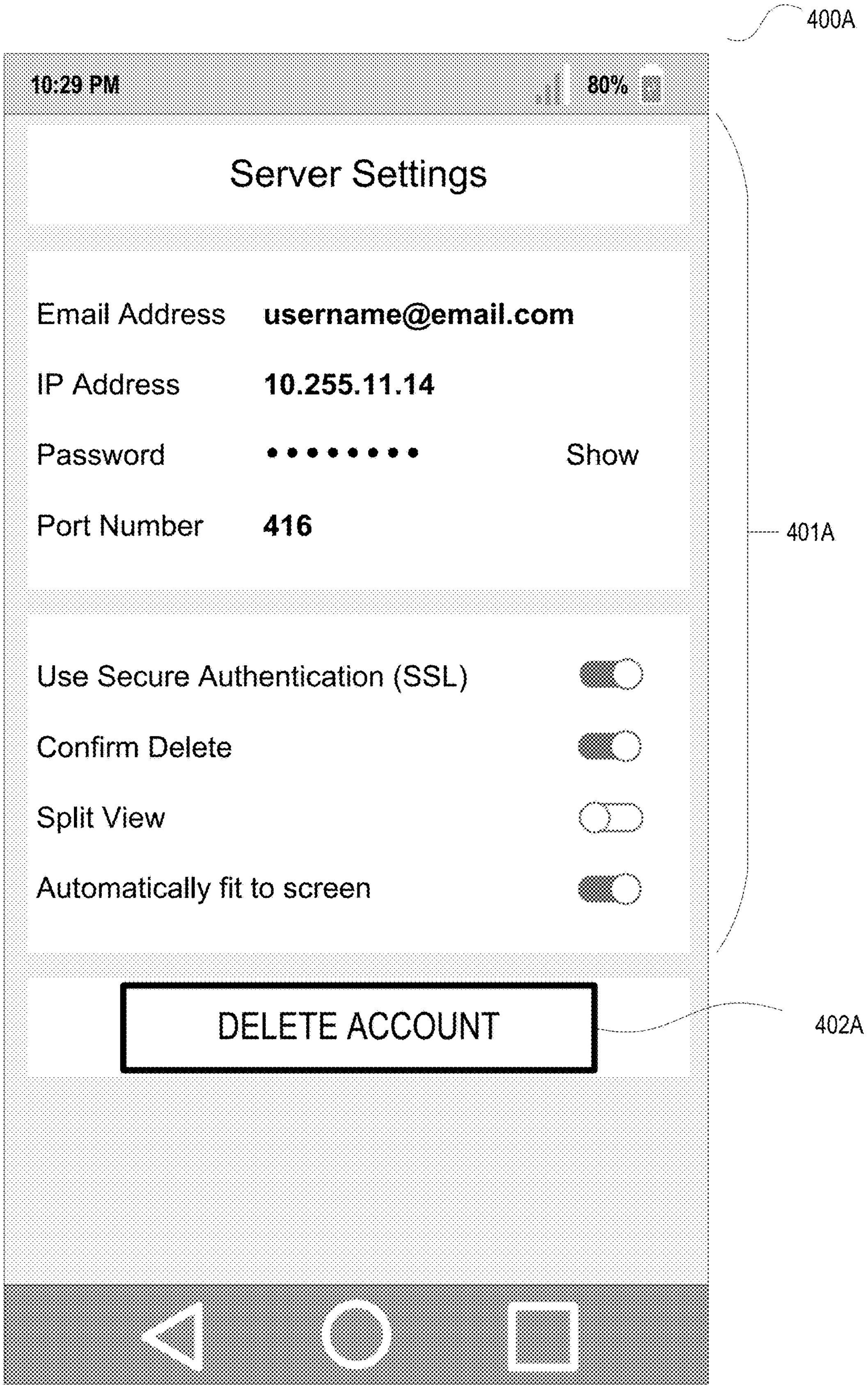

301
Virtualization Server
Virtual Machine A
332A
Control Program
320
Tools Stack
324
Virtual Disk A
326A
Virtual Processor A
328A
Virtual Machine B
332B
Guest OS A
330A
Virtual Disk B
326B
Virtual Processor B
328B
Virtual Machine C
332C
Guest OS B
330B
Virtual Disk C
326C
Virtual Processor C
328C
Hypervisor
302
Operating System
314
Hardware Layer
310
Physical Disk(s)
304
Physical Device(s)
306
Physical Processor(s)
308
Firmware 312
Physical Memory 316

FIG. 3



Server Settings

Email Address username@email.com

IP Address 10.255.11.14

Password •••••••• Show

Port Number 416

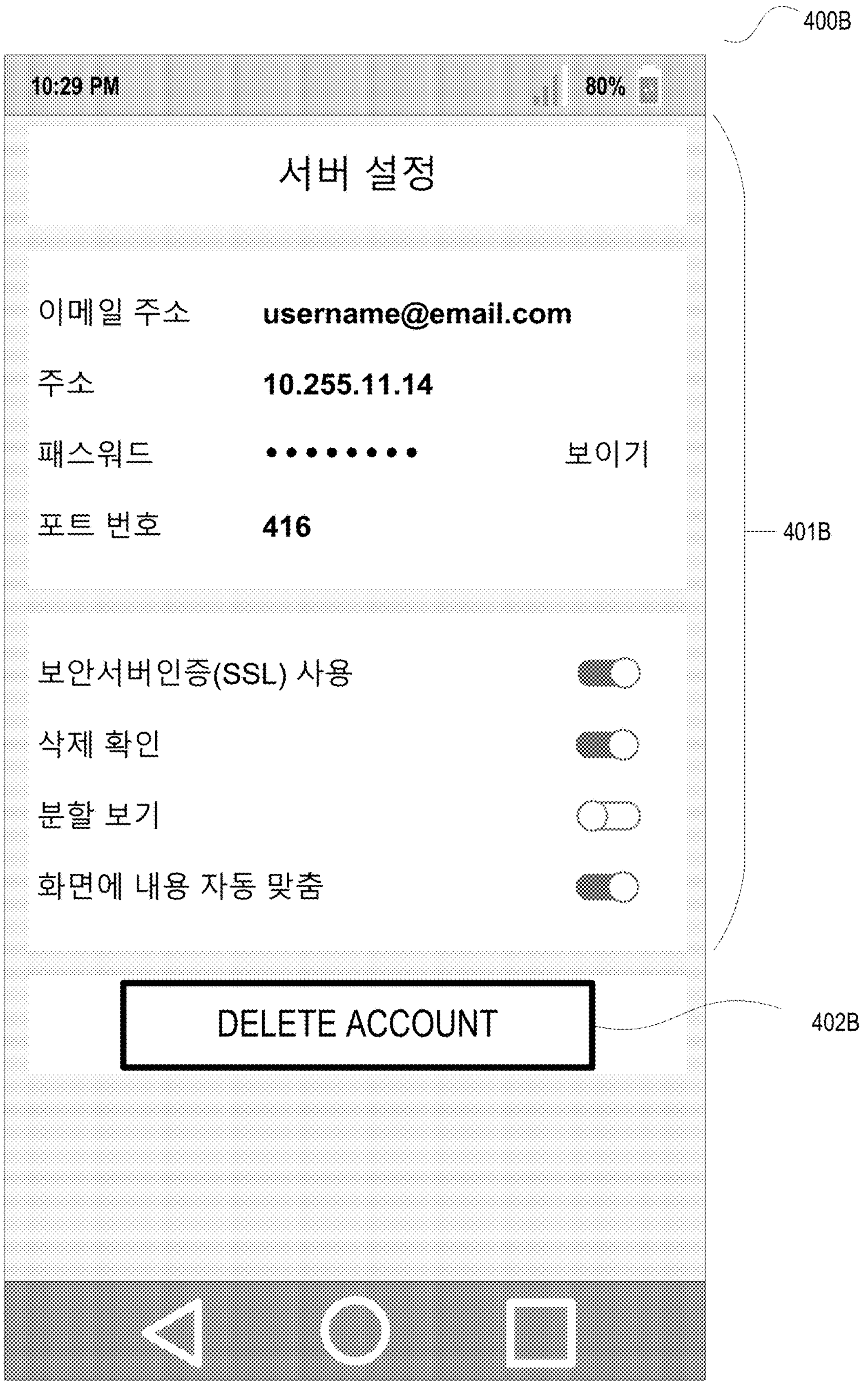
Use Secure Authentication (SSL) ●

Confirm Delete ●

Split View ○

Automatically fit to screen ●

FIG. 4A

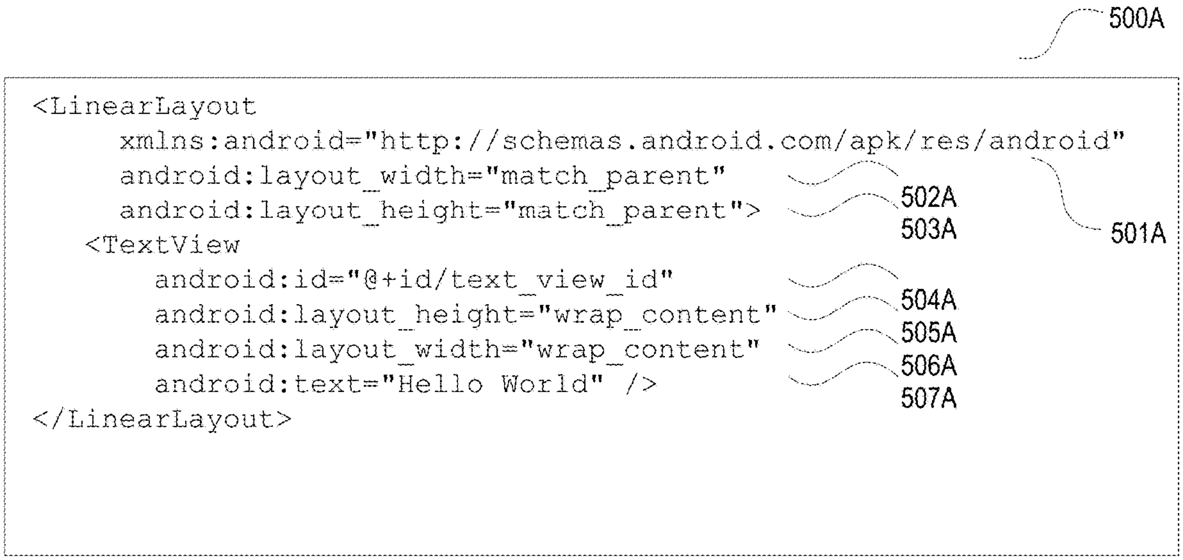


서버 설정

이메일 주소	username@email.com	
주소	10.255.11.14	
패스워드	•••••••••	보이기
포트 번호	416	

보안서버인증(SSL) 사용	●
삭제 확인	●
분할 보기	○
화면에 내용 자동 맞춤	●

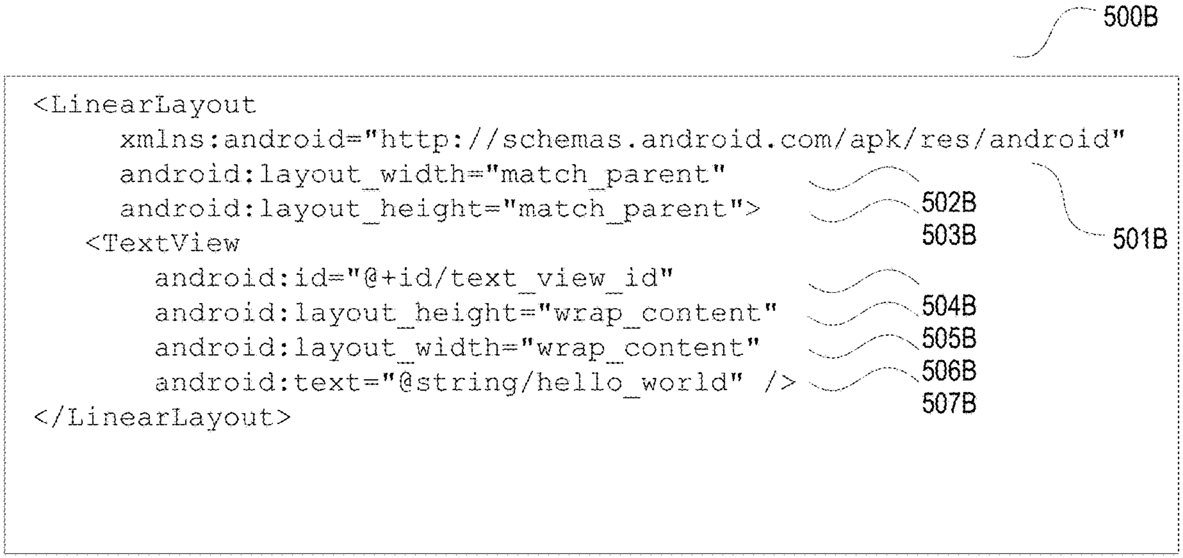
FIG. 4B



```
<LinearLayout
     xmlns:android="http://schemas.android.com/apk/res/android"
     android:layout_width="match_parent"
     android:layout_height="match_parent">
   <TextView
       android:id="@+id/text_view_id"
       android:layout_height="wrap_content"
       android:layout_width="wrap_content"
       android:text="Hello World" />
</LinearLayout>
```

500A
502A
503A
501A
504A
505A
506A
507A

FIG. 5A



```
<LinearLayout
     xmlns:android="http://schemas.android.com/apk/res/android"
     android:layout_width="match_parent"
     android:layout_height="match_parent">
   <TextView
       android:id="@+id/text_view_id"
       android:layout_height="wrap_content"
       android:layout_width="wrap_content"
       android:text="@string/hello_world" />
</LinearLayout>
```

500B
502B
503B
501B
504B
505B
506B
507B

FIG. 5B

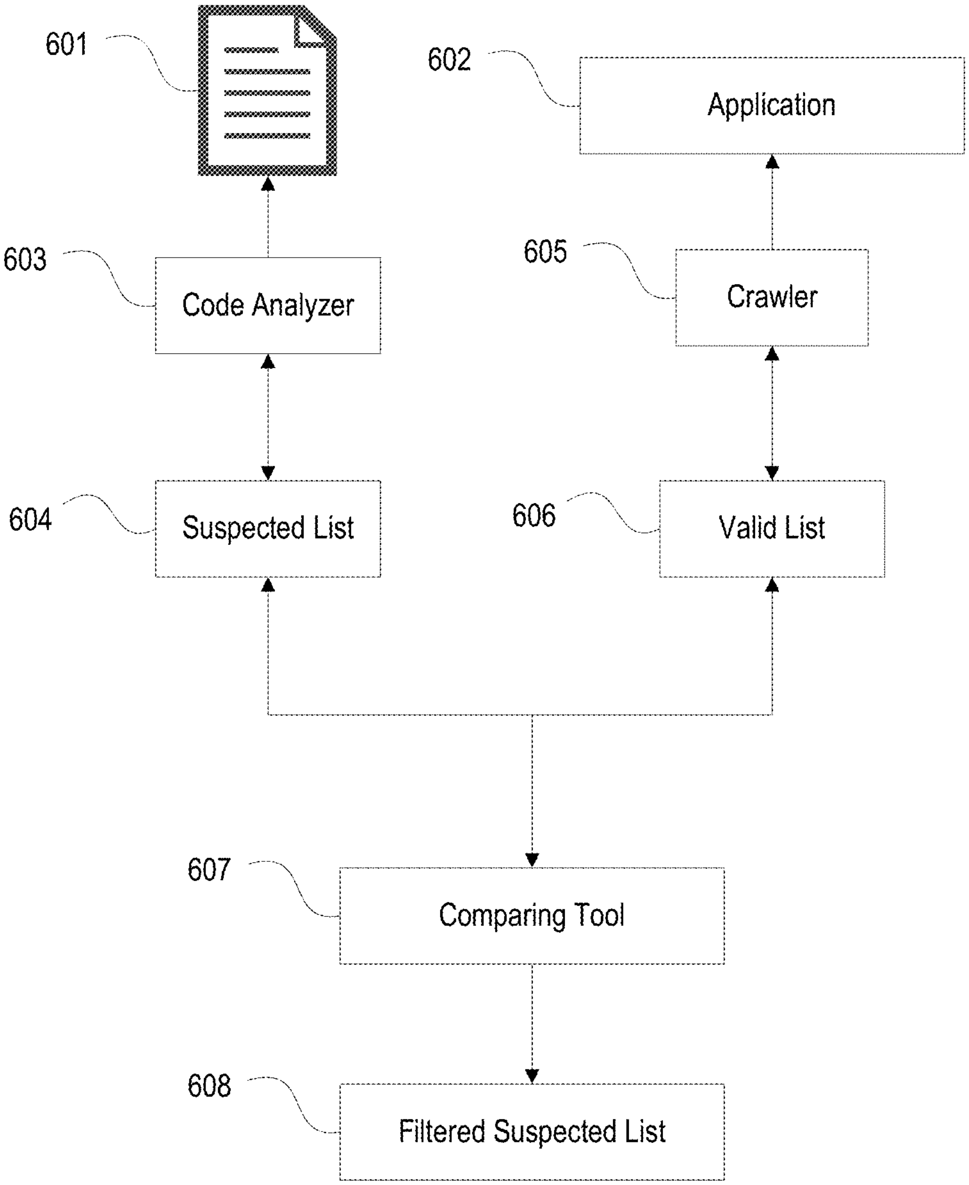

601
602
Application
603
Code Analyzer
605
Crawler
604
Suspected List
606
Valid List
607
Comparing Tool
608
Filtered Suspected List

FIG. 6

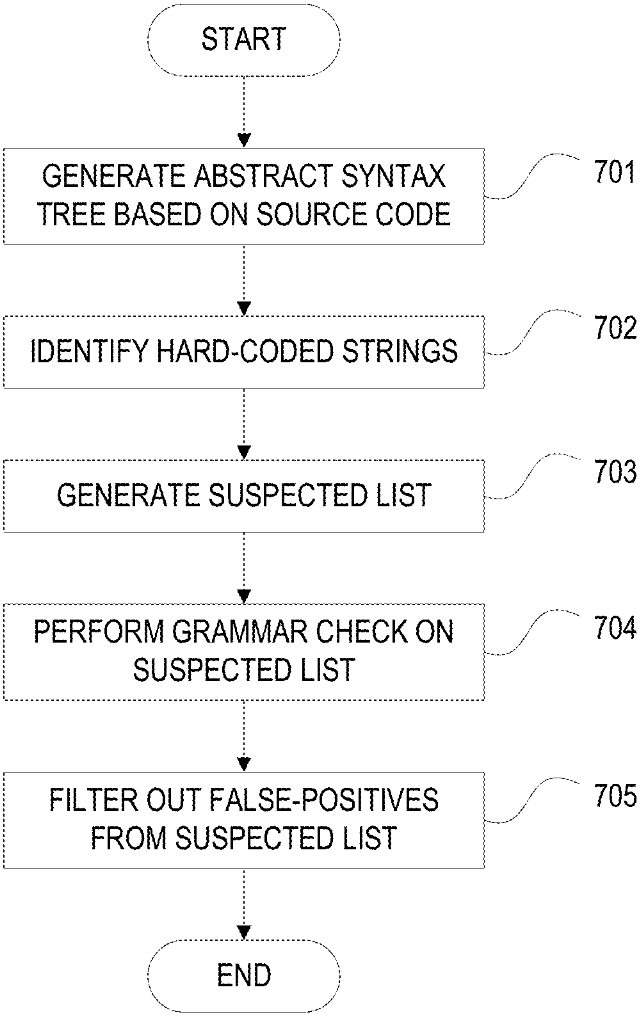
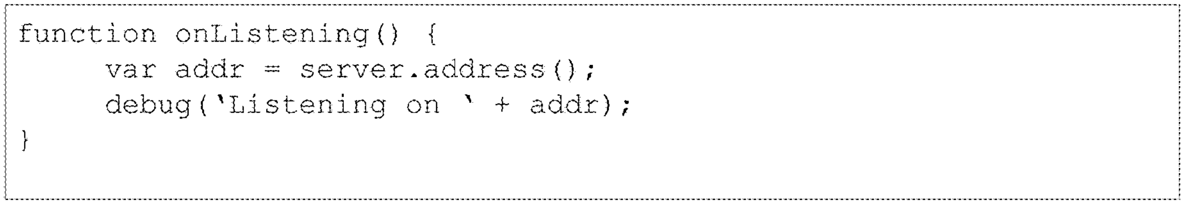
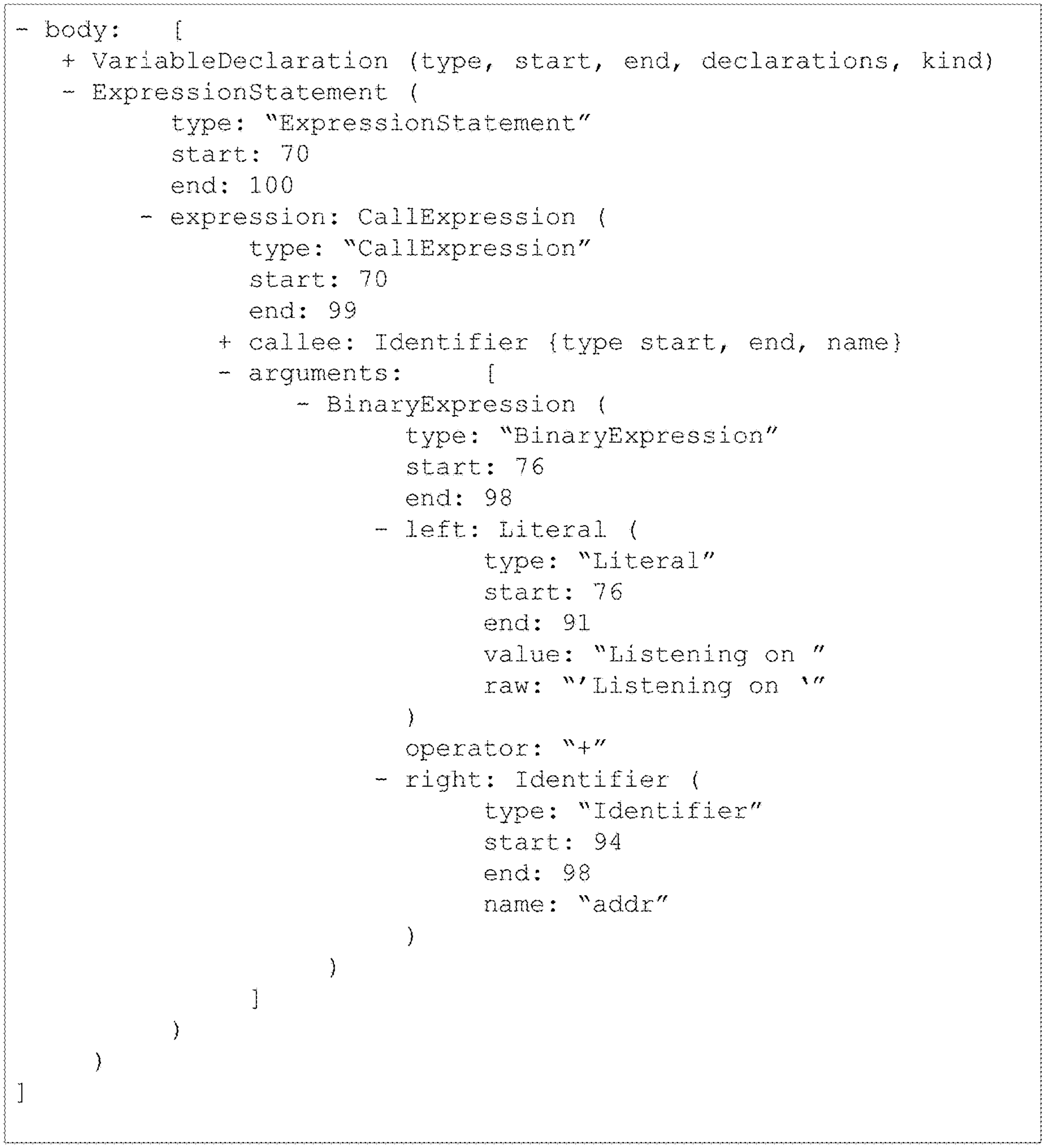

START
GENERATE ABSTRACT SYNTAX TREE BASED ON SOURCE CODE
701
IDENTIFY HARD-CODED STRINGS
702
GENERATE SUSPECTED LIST
703
PERFORM GRAMMAR CHECK ON SUSPECTED LIST
704
FILTER OUT FALSE-POSITIVES FROM SUSPECTED LIST
705
END

FIG. 7



```
function onListening() {
     var addr = server.address();
     debug('Listening on ' + addr);
}
```

FIG. 8A



```
- body:   [
   + VariableDeclaration (type, start, end, declarations, kind)
   - ExpressionStatement (
          type: "ExpressionStatement"
          start: 70
          end: 100
        - expression: CallExpression (
               type: "CallExpression"
               start: 70
               end: 99
             + callee: Identifier {type start, end, name}
             - arguments:     [
                  - BinaryExpression (
                         type: "BinaryExpression"
                         start: 76
                         end: 98
                       - left: Literal (
                              type: "Literal"
                              start: 76
                              end: 91
                              value: "Listening on "
                              raw: "'Listening on '"
                         )
                         operator: "+"
                       - right: Identifier (
                              type: "Identifier"
                              start: 94
                              end: 98
                              name: "addr"
                         )
                    )
               ]
          )
     )
]
```

FIG. 8B

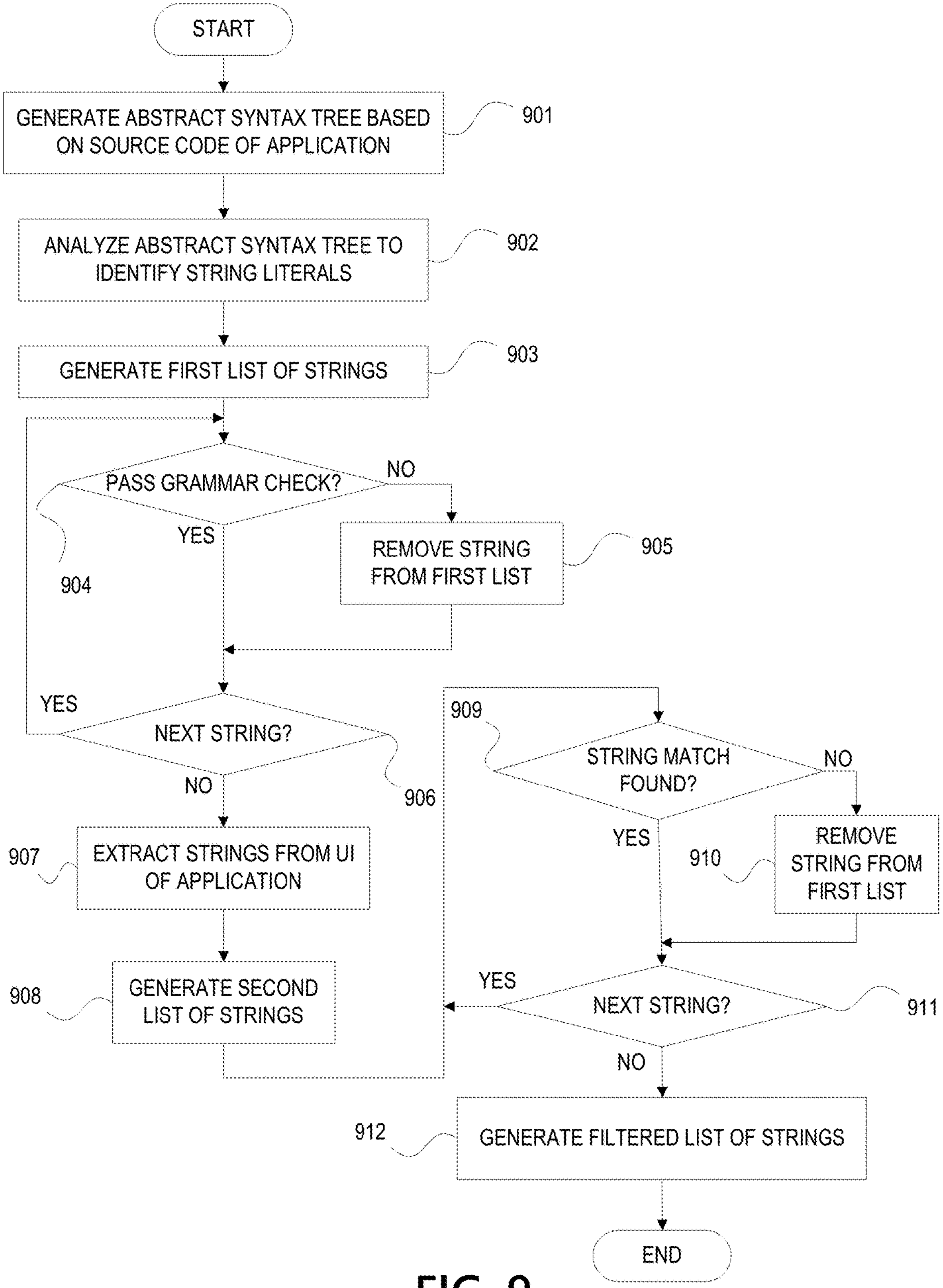

START
GENERATE ABSTRACT SYNTAX TREE BASED ON SOURCE CODE OF APPLICATION
901
ANALYZE ABSTRACT SYNTAX TREE TO IDENTIFY STRING LITERALS
902
GENERATE FIRST LIST OF STRINGS
903
PASS GRAMMAR CHECK?
NO
YES
904
REMOVE STRING FROM FIRST LIST
905
YES
NEXT STRING?
NO
906
EXTRACT STRINGS FROM UI OF APPLICATION
907
GENERATE SECOND LIST OF STRINGS
908
909
STRING MATCH FOUND?
NO
YES
910
REMOVE STRING FROM FIRST LIST
YES
NEXT STRING?
911
NO
912
GENERATE FILTERED LIST OF STRINGS
END

FIG. 9

DETECTING HARD-CODED STRINGS IN SOURCE CODE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Chinese PCT Application No. PCT/CN2019/092539, filed Jun. 24, 2019, titled Detecting Hard-Coded Strings In Source Code, which is hereby incorporated by reference in its entirety.

FIELD

Aspects described herein generally relate to software application development. More particularly, aspects the present disclosure relate to detection of hard-coded strings in source code.

BACKGROUND

Software development involves developers writing human-readable source code that consists of various elements such as identifiers, functions, variables, operators, and literals. The source code will then eventually be compiled and translated into machine code. However, including fixed string values, also known as string constants or string literals, directly in source code—the practice widely known as "hard coding"—is typically considered a bad practice because it renders the code more difficult to maintain and less adaptable especially for the purpose of localizing the software for a foreign market.

However, the practice of hard coding is difficult to completely prevent in practice, and it may be difficult to identify instances of hard-coded strings especially in large software development projects that involve millions of lines of source code spanning across thousands of files. An instance of a hard-coded string may not be discovered until a late phase in the software development cycle (e.g., while conducting a post-production quality assurance test), or worse yet, discovered by a consumer of the product after deployment. Conventional static code analysis tools may be able to automatically detect some hard-coded string candidates but these tools are also prone to producing many more false-positive results. Therefore, it would be beneficial to have an automated tool that can analyze source code and efficiently and accurately recognize hard-coded strings.

SUMMARY

The following presents a simplified summary of various aspects described herein. This summary is not an extensive overview, and is not intended to identify required or critical elements or to delineate the scope of the claims. The following summary merely presents some concepts in a simplified form as an introductory prelude to the more detailed description provided below.

The present specification is directed towards devices, systems, and methods for automated detection of hard-coded strings in source code.

According to an aspect of an example embodiment, a first list of strings may be generated via a processor. The first list of strings may include strings that are embedded in source code of an application. A second list of strings may also be generated. The second list of strings may include strings that are rendered via a user interface of the application. The first list of strings may be a suspected list of strings while the second list of strings may be a valid list of strings. Each

string of the first list of strings may then be compared against the strings of the second list of strings. Based on this comparison, a filtered list of strings may be generated by removing, from the first of strings, at least one string that does not have a match in the second list of strings.

Generating the second list of strings may be accomplished by using a crawler, an automation framework, and/or a hook to extract the strings that are rendered via the user interface of the application.

Generating the first list of strings may be accomplished by generating an abstract syntax tree (AST) based on the source code, and analyzing the AST to identify the strings that are embedded in the source code.

Generating the first list of strings may be accomplished by filtering out, from the strings embedded in the source code, at least one false-positive string that does not satisfy grammatical criteria.

The filtered list of strings may include at least part of the strings that are embedded in the source code and rendered via the user interface.

Generating the first list of strings may be accomplished by filtering out, from the strings embedded in the source code, at least one false-positive string that is used in an internal message of the application. The internal message may be a debug message, an error message, a log message, an exception, a comment, and/or a parameter.

These and additional aspects will be appreciated with the benefit of the disclosures discussed in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of aspects described herein and the advantages thereof may be acquired by referring to the following description in consideration of the accompanying drawings, in which like reference numbers indicate like features, and wherein:

FIG. **1** depicts an illustrative computer system architecture that may be used in accordance with one or more illustrative aspects described herein.

FIG. **2** depicts an illustrative remote-access system architecture that may be used in accordance with one or more illustrative aspects described herein.

FIG. **3** depicts an illustrative virtualized (hypervisor) system architecture that may be used in accordance with one or more illustrative aspects described herein.

FIG. **4**A depicts an illustrative graphical user interface that is rendered in English.

FIG. **4**B depicts an illustrative graphical user interface that is rendered for a non-English locale.

FIGS. **5**A and **5**B depict example code snippets.

FIG. **6** is a flow chart for an example method of analyzing source code and generating a suspected list of hard-coded strings.

FIG. **7** is a flow chart for an example method of analyzing source code and generating a suspected list of hard-coded strings.

FIG. **8**A illustrates an example code snippet, based on which an abstract syntax tree (AST) is generated.

FIG. **8**B illustrates an example AST.

FIG. **9** is a flow chart for an example method of detecting hard-coded strings in source code.

DETAILED DESCRIPTION

In the following description of the various embodiments, reference is made to the accompanying drawings identified above and which form a part hereof, and in which is shown by way of illustration various embodiments in which aspects described herein may be practiced. It is to be understood that other embodiments may be utilized and structural and functional modifications may be made without departing from the scope described herein. Various aspects are capable of other embodiments and of being practiced or being carried out in various different ways.

As a general introduction to the subject matter described in more detail below, aspects described herein are related to detection of hard-coded strings within source code. In particular, a suspected list of string literals may be collected from source code of an application. The suspected list may be filtered through a grammar check and further by a comparison with a valid list of strings extracted, in runtime, from the actual UI views of the application. False-positive results (e.g., internal application messages that do not cause concern for the developers) may be culled out to increase the accuracy of the detection. By automating the process of hard-code string detection, the development process may be more streamlined and the cost of maintaining, updating, and adapting the code may be decreased. Moreover, the overall user experience of using the localized version of the software may improve because fewer or no instances of inconsistent translation may be spotted by the end-user.

As used throughout this disclosure, the term "string" may refer to a sequence of characters (e.g., numbers, letters, symbols, etc.). A string may be represented digitally according to a particular character encoding scheme (e.g., ASCII, Unicode, etc.), and stored as a data structure. A string may be variously referred to as "text," "text string," "string asset," "text asset," etc. throughout this disclosure. As represented in source code, a string may be surrounded by a set of single or double quotation marks.

The term "literal" may refer to a notation of representing a fixed value in source code. A string literal (also referred to as "string constant") may be a literal of the string type.

The term "hard coding" (also stylized as "hard-coding" or "hardcoding") and its variants may broadly refer to the practice or product of embedding data directly into the source code of software. Thus, hard coding is different from obtaining the data from an external source (e.g., a resource file, a library, a user input, etc.) or generating the data at run-time. More specifically, hard coding may refer to the practice or product of embedding a string literal into the source code. Hard-coded strings or string literals may include not only text that is displayed or otherwise exposed to the user (especially the end-user) via a user interface (UI), but also other types of text that is not necessarily exposed to the user such as a debug message, an error message, a log message, an exception, a comment, a parameter, etc. Of special interest to this disclosure is detection (for the purpose of removal or externalization) of a type of hard-coded strings that that eventually show up as UI text. For example, a hard-coded string may more specifically refer to any text embedded directly in source code of the application and is visible or otherwise exposed to the end-user via an output device (e.g., a display device, a speaker, etc.) and the application's UI. The presented text may be part of a graphical user interface (GUI) element, such as a button, a dialog box, a text box, a menu, a status bar, etc. In other words, a hard-coded string may refer to any text that is embedded in the source code and is also visible to the end-user. However, the embedded form of a hard-coded string may not always look exactly like the text that is eventually presented to the end-user. For example, the hard-coded string, as embedded in the source code, may partially include placeholder text such as string formatting operators (e.g., "% d," "% s," "% n," etc.) that are later replaced with other text at compile-time or at run-time.

The term "localization" may broadly refer to a process of adapting software and/or hardware, which was originally developed for sale in one region or country, for deployment in another region or country. Thus, localization often involves translation of assets, such as text and graphics, from one language to another language. For example, a software product originally developed for use in an English-speaking region may be localized to be marketed and sold in a different region where Spanish is a predominantly spoken language. As another example, video games originally developed in the English language for the U.S. market are often additionally localized into French, Italian, German, and Spanish (colloquially referred to as "FIGS") for the European market.

It is to be understood that the phraseology and terminology used herein are for the purpose of description and should not be regarded as limiting. Rather, the phrases and terms used herein are to be given their broadest interpretation and meaning. The use of "including" and "comprising" and variations thereof is meant to encompass the items listed thereafter and equivalents thereof as well as additional items and equivalents thereof. The use of the terms "connected," "coupled," and similar terms, is meant to include both direct and indirect connecting and coupling.

Computing Architecture

Computer software, hardware, and networks may be utilized in a variety of different system environments, including standalone, networked, remote-access (also known as remote desktop), virtualized, and/or cloud-based environments, among others. FIG. **1** illustrates one example of a system architecture and data processing device that may be used to implement one or more illustrative aspects described herein in a standalone and/or networked environment. Various network nodes **103**, **105**, **107**, and **109** may be interconnected via wide area network (WAN) **101**, such as the Internet. Other networks may also or alternatively be used, including private intranets, corporate networks, local area networks (LAN), metropolitan area networks (MAN), wireless networks, personal networks (PAN), and the like. Network **101** is for illustration purposes and may be replaced with fewer or additional computer networks. Local area network **133** may have one or more of any known LAN topology and may use one or more of a variety of different protocols, such as Ethernet. Devices **103**, **105**, **107**, and **109** and other devices (not shown) may be connected to one or more of the networks via twisted pair wires, coaxial cable, fiber optics, radio waves, or other communication media.

The term "network" as used herein and depicted in the drawings refers not only to systems in which remote storage devices are coupled together via one or more communication paths, but also to stand-alone devices that may be coupled, from time to time, to such systems that have storage capability. Consequently, the term "network" includes not only a "physical network" but also a "content network," which is comprised of the data—attributable to a single entity—which resides across all physical networks.

The components may include data server **103**, web server **105**, and client computers **107**, **109**. Data server **103** provides overall access, control, and administration of databases and control software for performing one or more illustrative aspects describe herein. Data server **103** may be connected to web server **105**, through which users interact with and obtain data as requested. Alternatively, data server **103** may act as a web server itself and be directly connected to WAN **101**. Data server **103** may be connected to web server **105** through local area network **133**, wide area network **101** (e.g., the Internet), via direct or indirect connection, or via some other network. Users may interact with data server **103** using remote computers **107**, **109**, e.g., using a web browser to connect to data server **103** via one or more externally exposed web sites hosted by web server **105**. Client computers **107**, **109** may be used in concert with data server **103** to access data stored therein, or may be used for other purposes. For example, from client device **107** a user may access web server **105** using an Internet browser, or by executing a software application that communicates with web server **105** and/or data server **103** over a computer network (such as the Internet).

Servers and applications may be combined on the same physical machines, and retain separate virtual or logical addresses, or may reside on separate physical machines. FIG. **1** illustrates just one example of a network architecture that may be used, and those of skill in the art will appreciate that the specific network architecture and data processing devices used may vary, and are secondary to the functionality that they provide, as further described herein. For example, services provided by web server **105** and data server **103** may be combined on a single physical server.

Each component **103**, **105**, **107**, **109** may be any type of known computer, server, or data processing device. Data server **103** may include, for example, processor **111** controlling overall operation of data server **103**. Data server **103** may further include random access memory (RAM) **113**, read-only memory (ROM) **115**, network interface **117**, input/output (I/O) interfaces **119** (e.g., keyboard, mouse, display, printer, etc.), and memory **121**. I/O interfaces **119** may include a variety of interface units and drives for reading, writing, displaying, and/or printing data or files. Memory **121** may further store operating system software **123** for controlling overall operation of data processing device **103**, control logic **125** for instructing data server **103** to perform aspects described herein, and other application software **127** providing secondary, support, and/or other functionality which may be used in conjunction with aspects described herein. Control logic **125** may also be referred to herein as data server software **125**. Functionality of data server software **125** may include operations or decisions made automatically (e.g., without human user intervention) based on rules coded into control logic **125**, made manually by a user providing input into the system, and/or a combination of automatic processing based on user input (e.g., queries, data updates, etc.).

Memory **121** may also store data used in performance of one or more aspects described herein, and may include first database **129** and/or second database **131**. In some embodiments, first database **129** may include second database **131** (e.g., as a separate table, report, etc.). That is, the information can be stored in a single database, or separated into different logical, virtual, or physical databases, depending on system design. Devices **105**, **107**, and **109** may have similar or different architecture as described with respect to device **103**. Those of skill in the art will appreciate that the functionality of data processing device **103** (or device **105**, **107**, or **109**) as described herein may be spread across multiple data processing devices, for example, to distribute processing load across multiple computers, to segregate transactions based on geographic location, user access level, quality of service (QoS), etc.

One or more aspects may be embodied in computer-usable or computer-readable data and/or computer-executable instructions, such as in one or more program modules, executed by one or more computers or other devices as described herein. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types when executed by a processor in a computer or other device. The modules may be written in a source code programming language that is subsequently compiled for execution, or may be written in a scripting language such as (but not limited to) Hypertext Markup Language (HTML) or Extensible Markup Language (XML). The computer executable instructions may be stored on a computer-readable medium such as a nonvolatile storage device. Any suitable computer-readable storage media may be utilized, including hard disks, compact disc read-only memories (CD-ROMs), optical storage devices, magnetic storage devices, and/or any combination thereof. In addition, various transmission (non-storage) media representing data or events as described herein may be transferred between a source and a destination in the form of electromagnetic waves traveling through signal-conducting media such as metal wires, optical fibers, and/or wireless transmission media (e.g., air and/or space). Various aspects described herein may be embodied as a method, a data processing system, or a computer program product. Therefore, various functionalities may be embodied in whole or in part in software, firmware, and/or hardware or hardware equivalents such as integrated circuits (ICs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), virtual machines, and the like. Particular data structures may be used to more effectively implement one or more aspects described herein, and such data structures are contemplated within the scope of computer-executable instructions and computer-usable data described herein.

With further reference to FIG. **2**, one or more aspects described herein may be implemented in a remote-access environment. FIG. **2** depicts an example system architecture including computing device **201** in an illustrative computing environment **200** that may be used according to one or more illustrative aspects described herein. Computing device **201** may be used as server **206**A in a single-server or multi-server desktop virtualization system (e.g., a remote-access or cloud system) and can be configured to provide virtual machines for client access devices. Computing device **201** may have processor **203** for controlling overall operation of device **201** and its associated components, including RAM **205**, ROM **207**, input/output (I/O) interfaces **209**, and memory **215**.

I/O interfaces **209** may include a mouse, a keyboard, a keypad, a touch screen, a scanner, a sensor, an optical reader, a camera, a microphone, a stylus, and/or other input device (s) through which a user of computing device **201** may provide input, and may also include one or more of a speaker for providing audio output and one or more of a video display device for providing textual, audiovisual, and/or graphical output. Software may be stored within memory **215** and/or other storage to provide instructions to processor **203** for configuring computing device **201** into a special-purpose computing device in order to perform various functions as described herein. For example, memory **215** may store software used by computing device **201**, such as operating system **217**, application programs **219**, and other associated data **221** (e.g., a database).

Computing device **201** may operate in a networked environment supporting connections to one or more remote computers, such as terminals **240** (also referred to as client devices and/or client machines). Terminals **240** may be personal computers (PCs), mobile devices, smartphones, laptop computers, tablets, wearable computing devices, and/

or servers that include some or all of the elements described above with respect to computing device **103** or **201**. The network connections depicted in FIG. **2** may include local area network (LAN) **225** and wide area network (WAN) **229**, but may also include other networks. When used in a LAN networking environment, computing device **201** may be connected to LAN **225** through a LAN interface or adapter **223** (e.g., a network interface controller). When used in a WAN networking environment, computing device **201** may include a modem or other wide area network interface **227** for establishing communications over WAN **229**, such as computer network **230** (e.g., the Internet). It will be appreciated that the network connections shown are illustrative and other means of establishing a communications link between the computers may be used. Computing device **201** and/or terminals **240** may also be mobile terminals (e.g., mobile phones, smartphones, personal digital assistants (PDAs), notebooks, etc.) including various other components, such as a battery, a speaker, and antennas (not shown).

Aspects described herein may also be operational with numerous other general-purpose or special-purpose computing system environments or configurations. Examples of other computing systems, environments, and/or configurations that may be suitable for use with aspects described herein may include, but are not limited to, PCs, server computers, hand-held or laptop devices, multiprocessor systems, set-top boxes, programmable consumer electronics, network PCs, minicomputers, mainframe computers, distributed computing environments that include any of the above systems or devices, and the like.

As shown in FIG. **2**, one or more client devices **240** may be in communication with one or more servers **206**A-**206**N (generally referred to herein as "server(s) **206**"). In one embodiment, computing environment **200** may include a network appliance installed between server(s) **206** and client machine(s) **240**. The network appliance may manage client/server connections, and in some cases can load balance client connections amongst a plurality of backend servers **206**.

Client machine(s) **240** may in some embodiments be referred to as a single client machine **240** or a single group of client machines **240**, while server(s) **206** may be referred to as a single server **206** or a single group of servers **206**. In some embodiments a single client machine **240** may communicate with more than one server **206**, while in other embodiments, a single server **206** may communicate with more than one client machine **240**. In yet other embodiments, a single client machine **240** may communicate with a single server **206**.

Client machine **240** may, in some embodiments, be referred to as any one of the following non-exhaustive terms: a client machine, a client, a client computer, a client device, a client access device, a client computing device, a local machine, a remote machine, a client node, an endpoint, an endpoint node, a terminal, a user terminal, a user device, etc. Server **206**, in some embodiments, may be referred to as any one of the following non-exhaustive terms: a server, a local machine, a remote machine, a server farm, a host, a host device, a host computing device, etc.

In some embodiments, client machine **240** may be a virtual machine. A virtual machine may refer to a software emulated instance of a physical computer. The virtual machine may be managed by a Type 1 or Type 2 hypervisor, for example, a hypervisor developed by Citrix Systems®, IBM®, VMware®, or any other hypervisor. In some aspects, the hypervisor may execute on server **206** or on client **240**.

In some embodiments, client device **240** may display application output generated by an application remotely executing on server **206** or other remotely located machine. In these embodiments, client device **240** may execute a virtual machine receiver program or application to display the output in an application window, a browser, or other output window. In one example, the remotely executed application is a desktop, while in other examples, the application is an application that generates or presents a desktop. A desktop may include a graphical shell providing a user interface for an instance of an operating system in which local and/or remote applications can be integrated. Applications, as used herein, are programs that execute after an instance of an operating system (and, optionally, also the desktop) has been loaded.

Server **206**, in some embodiments, may use a remote presentation protocol or other program to send data to a thin-client or remote-display application executing on the client to present display output generated by an application executing on server **206**. The thin-client or remote-display protocol may be any one of the following non-exhaustive list of protocols: the Independent Computing Architecture (ICA) protocol developed by Citrix Systems, Inc. of Ft. Lauderdale, Fla.; or the Remote Desktop Protocol (RDP) developed by the Microsoft Corporation of Redmond, Wash.

A remote computing environment may include more than one server **206**A-**206**N such that servers **206**A-**206**N are logically grouped together into server farm **206**, for example, in a cloud computing environment. Server farm **206** may include servers **206** that are geographically dispersed while logically grouped together, or servers **206** that are located proximate to each other (e.g., housed within the same physical facility) while logically grouped together. Geographically dispersed servers **206**A-**206**N within server farm **206** may, in some embodiments, communicate using a WAN, a MAN, or a LAN, where different geographic regions may be characterized as: different continents, different regions of a continent, different countries, different states, different cities, different campuses, different buildings, different rooms, or any combination of the preceding geographical locations. In some embodiments, server farm **206** may be administered as a single entity, while in other embodiments, server farm **206** may include multiple server farms.

In some embodiments, a server farm may include servers **206** that execute a substantially similar type of operating system platform (e.g., Windows®, macOS®, Unix®, Linux®, iOS®, Android®, Symbian®, etc.). In other embodiments, server farm **206** may include a first group of one or more servers that execute a first type of operating system platform, and a second group of one or more servers that execute a second type of operating system platform.

Server **206** may be configured as any type of server, as needed, e.g., a file server, an application server, a web server, a proxy server, an appliance, a network appliance, a gateway, an application gateway, a gateway server, a virtualization server, a deployment server, a Secure Sockets Layer (SSL) virtual private network (VPN) server, a firewall, a web server, a master application server, a server executing an active directory, or a server executing an application acceleration program that provides firewall functionality, application functionality, or load balancing functionality. Other server types may also be used.

Some embodiments may include first server **206**A that receives requests from client machine **240**, forwards the request to second server **206**B (not shown), and responds to the request generated by client machine **240** with a response from second server **206**B (not shown). First server **206**A may acquire an enumeration of applications available to client machine **240** as well as address information associated with application server **206** hosting an application identified within the enumeration of applications. First server **206**A may then present a response to the client's request using a web interface, and communicate directly with client **240** to provide client **240** with access to an identified application. One or more clients **240** and/or one or more servers **206** may transmit data over network **230**, e.g., network **101**.

FIG. **3** shows a high-level architecture of an illustrative desktop virtualization system. As shown, the desktop virtualization system may be a single-server or multi-server system, or a cloud system, including at least one virtualization server **301** configured to provide virtual desktops and/or virtual applications to one or more client access devices **240**. As used herein, a desktop may refer to a graphical environment (e.g., a graphical user interface) or space in which one or more applications may be hosted and/or executed. A desktop may include a graphical shell providing a user interface for an instance of an operating system in which local and/or remote applications can be integrated. Applications may include programs that execute after an instance of an operating system (and, optionally, also the desktop) has been loaded. Each instance of the operating system may be physical (e.g., one operating system per physical device) or virtual (e.g., many instances of an OS running on a single physical device). Each application may be executed on a local device, or executed on a remotely located device (e.g., remoted).

Computer device **301** may be configured as a virtualization server in a virtualization environment, for example, a single-server, multi-server, or cloud computing environment. Virtualization server **301** illustrated in FIG. **3** may be deployed as and/or implemented by one or more embodiments of server **206** illustrated in FIG. **2** or by other known computing devices. Included in virtualization server **301** is hardware layer **310** that may include one or more physical disks **304**, one or more physical devices **306**, one or more physical processors **308**, and one or more physical memories **316**. In some embodiments, firmware **312** may be stored within a memory element in physical memory **316** and be executed by one or more of physical processors **308**. Virtualization server **301** may further include operating system **314** that may be stored in a memory element in physical memory **316** and executed by one or more of physical processors **308**. Still further, hypervisor **302** may be stored in a memory element in physical memory **316** and be executed by one or more of physical processors **308**. Presence of operating system **314** may be optional such as in a case where the hypervisor **302** is a Type A hypervisor.

Executing on one or more of physical processors **308** may be one or more virtual machines **332**A-C (generally **332**). Each virtual machine **332** may have virtual disk **326**A-C and virtual processor **328**A-C. In some embodiments, first virtual machine **332**A may execute, using virtual processor **328**A, control program **320** that includes tools stack **324**. Control program **320** may be referred to as a control virtual machine, Domain 0, Dom0, or other virtual machine used for system administration and/or control. In some embodiments, one or more virtual machines **332**B-C may execute, using virtual processor **328**B-C, guest operating system **330**A-B (generally **330**).

Physical devices **306** may include, for example, a network interface card, a video card, an input device (e.g., a keyboard, a mouse, a scanner, etc.), an output device (e.g., a monitor, a display device, speakers, a printer, etc.), a storage device (e.g., an optical drive), a Universal Serial Bus (USB) connection, a network element (e.g., router, firewall, network address translator, load balancer, virtual private network (VPN) gateway, Dynamic Host Configuration Protocol (DHCP) router, etc.), or any device connected to or communicating with virtualization server **301**. Physical memory **316** in hardware layer **310** may include any type of memory. Physical memory **316** may store data, and in some embodiments may store one or more programs, or set of executable instructions. FIG. **3** illustrates an embodiment where firmware **312** is stored within physical memory **316** of virtualization server **301**. Programs or executable instructions stored in physical memory **316** may be executed by the one or more processors **308** of virtualization server **301**.

Virtualization server **301** may also include hypervisor **302**. In some embodiments, hypervisor **302** may be a program executed by processors **308** on virtualization server **301** to create and manage any number of virtual machines **332**. Hypervisor **302** may be referred to as a virtual machine monitor, or platform virtualization software. In some embodiments, hypervisor **302** may be any combination of executable instructions and hardware that monitors virtual machines **332** executing on a computing machine. Hypervisor **302** may be a Type 2 hypervisor, where the hypervisor executes within operating system **314** executing on virtualization server **301**. Virtual machines may then execute at a layer above hypervisor **302**. In some embodiments, the Type 2 hypervisor may execute within the context of a user's operating system such that the Type 2 hypervisor interacts with the user's operating system. In other embodiments, one or more virtualization servers **301** in a virtualization environment may instead include a Type 1 hypervisor (not shown). A Type 1 hypervisor may execute on virtualization server **301** by directly accessing the hardware and resources within hardware layer **310**. That is, while Type 2 hypervisor **302** accesses system resources through host operating system **314**, as shown, a Type 1 hypervisor may directly access all system resources without host operating system **314**. A Type 1 hypervisor may execute directly on one or more physical processors **308** of virtualization server **301**, and may include program data stored in physical memory **316**.

Hypervisor **302**, in some embodiments, may provide virtual resources to guest operating systems **330** or control programs **320** executing on virtual machines **332** in any manner that simulates operating systems **330** or control programs **320** having direct access to system resources. System resources can include, but are not limited to, physical devices **306**, physical disks **304**, physical processors **308**, physical memory **316**, and any other component included in hardware layer **310** of virtualization server **301**. Hypervisor **302** may be used to emulate virtual hardware, partition physical hardware, virtualize physical hardware, and/or execute virtual machines that provide access to computing environments. In still other embodiments, hypervisor **302** may control processor scheduling and memory partitioning for virtual machine **332** executing on virtualization server **301**. Examples of hypervisor **302** may include those manufactured by VMWare, Inc., of Palo Alto, Calif.; Xen Project® hypervisor, an open source product whose development is overseen by the open source XenProject.org community; Hyper-V®, Virtual Server®, and Virtual PC® hypervisors provided by Microsoft Corporation of Redmond, Wash.; or others. In some embodiments, virtualization server **301** may execute hypervisor **302** that creates a virtual machine platform on which guest operating systems **330** may execute. In these embodiments, virtualization server **301** may be referred to as a host server. An example of such a virtualization server is Citrix Hypervisor® provided by Citrix Systems, Inc., of Fort Lauderdale, Fla.

Hypervisor **302** may create one or more virtual machines **332**B-C (generally **332**) in which guest operating systems **330** execute. In some embodiments, hypervisor **302** may load a virtual machine image to create virtual machine **332**. The virtual machine image may refer to a collection of data, states, instructions, etc. that make up an instance of a virtual machine. In other embodiments, hypervisor **302** may execute guest operating system **330** within virtual machine **332**. In still other embodiments, virtual machine **332** may execute guest operating system **330**.

In addition to creating virtual machines **332**, hypervisor **302** may control the execution of at least one virtual machine **332**. In other embodiments, hypervisor **302** may present at least one virtual machine **332** with an abstraction of at least one hardware resource provided by virtualization server **301** (e.g., any hardware resource available within hardware layer **310**). In other embodiments, hypervisor **302** may control the manner in which virtual machines **332** access physical processors **308** available in virtualization server **301**. Controlling access to physical processors **308** may include determining whether virtual machine **332** should have access to processor **308**, and how physical processor capabilities are presented to virtual machine **332**.

As shown in FIG. **3**, virtualization server **301** may host or execute one or more virtual machines **332**. Virtual machine **332** may be a set of executable instructions and/or user data that, when executed by processor **308**, may imitate the operation of a physical computer such that virtual machine **332** can execute programs and processes much like a physical computing device. While FIG. **3** illustrates an embodiment where virtualization server **301** hosts three virtual machines **332**, in other embodiments virtualization server **301** may host any number of virtual machines **332**. Hypervisor **302**, in some embodiments, may provide each virtual machine **332** with a unique virtual view of the physical hardware, including memory **316**, processor **308**, and other system resources **304**, **306** available to that virtual machine **332**. In some embodiments, the unique virtual view may be based on one or more of virtual machine permissions, application of a policy engine to one or more virtual machine identifiers, a user accessing a virtual machine, the applications executing on a virtual machine, networks accessed by a virtual machine, or any other desired criteria. For instance, hypervisor **302** may create one or more unsecure virtual machines **332** and one or more secure virtual machines **332**. Unsecure virtual machines **332** may be prevented from accessing resources, hardware, memory locations, and programs that secure virtual machines **332** may be permitted to access. In other embodiments, hypervisor **302** may provide each virtual machine **332** with a substantially similar virtual view of the physical hardware, memory, processor, and other system resources available to virtual machines **332**.

Each virtual machine **332** may include virtual disk **326**A-C (generally **326**) and virtual processor **328**A-C (generally **328**.) Virtual disk **326**, in some embodiments, may be a virtualized view of one or more physical disks **304** of virtualization server **301**, or a portion of one or more physical disks **304** of virtualization server **301**. The virtualized view of physical disks **304** may be generated, provided, and managed by hypervisor **302**. In some embodiments, hypervisor **302** may provide each virtual machine **332** with a unique view of physical disks **304**. Thus, in these embodiments, particular virtual disk **326** included in each virtual machine **332** may be unique when compared with other virtual disks **326**.

Virtual processor **328** may be a virtualized view of one or more physical processors **308** of virtualization server **301**. In some embodiments, the virtualized view of physical processors **308** may be generated, provided, and managed by hypervisor **302**. In some embodiments, virtual processor **328** may have substantially all of the same characteristics of at least one physical processor **308**. In other embodiments, virtual processor **308** may provide a modified view of physical processors **308** such that at least some of the characteristics of virtual processor **328** are different from the characteristics of the corresponding physical processor **308**.

Detection of Hard-Coded Strings in Source Code

FIG. **4**A depicts an illustrative graphical user interface that is rendered in English. Specifically, depicted in the figure is user interface screen **400**A of an example mobile application. User interface screen **400**A is configured for the "en-US" (English-United States) locale. Thus, the GUI is rendered in English, as shown by various GUI elements **401**A, **402**A. A developer of the application may have chosen to store the text assets (e.g., strings) in a file that is separate from the source code of the application. For example, all the localized strings corresponding to the "en-US" locale may have been stored in a resource file named "stringtable_en-US.xml" apart from the associated source code file named "com.mycompany.myapp.java." When UI screen **400**A is rendered, the machine code for rendering the screen may access "stringtable_en-US.xml" in runtime to retrieve appropriate string assets and populate the UI screen **400**A with the retrieved string assets. Alternatively, the string assets of "stringtable_en-US.xml" may be retrieved during compile time and embedded in the resulting machine code.

FIG. **4**B depicts an illustrative graphical user interface that is rendered for a non-English locale. In particular, user interface screen **400**B may be equivalent to user interface screen **400**A of FIG. **4**A but is configured for the "kr-KR" (Korean-Korea) locale, which is a non-English locale. The developer of the application may have chosen to store the text assets (e.g., localized strings) in a file that is separate from the source code of the application. For example, all the localized strings corresponding to the "KR" (Korea) locale may have been stored a resource file named "stringtable_kr-KR.xml" apart from the source code. However, even though a major portion of the UI is illustrated in FIG. **4**B as being rendered in the Korean language, as exemplified by GUI elements **401**, some element such as GUI element **402**B is still featuring a string asset in English. This may likely be a result of the text asset corresponding to GUI element **402**B being directly embedded ("hard-coded") into the source code instead of being stored and retrieved from the separate resource file "stringtable_kr-KR.xml." This type of error may not always affect functionality of the application, encountering such non-conforming GUI elements may be jarring to the end-user and thus negatively affect the overall user experience.

As this example illustrates, having such hard-coded strings embedded throughout the source code may make it very difficult and costly to maintain the code or to adapt the code for localization. The problem is further compounded when, as is a common practice in the software industry, the source code is written by software engineers while the translation work is performed by translators who are more linguistically minded. The software engineers and developers are typically not capable of fixing translation errors in their source code, and the translators may not be given access to directly edit the source code in order to prevent unauthorized and/or inadvertent tampering. It is also a common practice for software manufacturers to create a software product for a domestic market (e.g., North America) first, and then later make a business decision to create versions of the software for international markets (e.g., Europe, Asia, Africa, etc.). If some or all of the UI-exposed string assets (i.e., string assets that will be visible to end-users via a UI) happen to be hard-coded into the original source code, localizing the software for the international markets may become significantly costlier and more inefficient because one may be required to identify every instance of hard-coded strings across multiple source code files and modify them in a consistent manner. This process will likely need to be repeated every time a new locale is added to the software or any incremental updates are needed for the string assets. The source code itself may become bloated with an excessive amount of conditional statements required to handle multiple versions of string assets.

FIGS. **5**A and **5**B depict example code snippets. In particular, code **500**A of FIG. **5**A and code **500**B of FIG. **5**B may each be a snippet from an XML file that defines a layout of a GUI view for a mobile application. For example, code **500**A contains several string literals **501**A through **507**A. However, string literals **501**A through **506**B may be various parameters that are only used internally within the application while string literal **507**A ("Hello World") may be a hard-coded text string that is displayed to the end-user via the GUI. Code **500**B of FIG. **5**A is similar to code **500**A but string literal **507**B of code **500**B is now replaced with a parameter that references a resource file (e.g., a string table "@ string") and a key (e.g., "hello_world"). The disclosure will now turn to descriptions of various embodiments for detecting hard-coded strings in source code.

FIG. **6** is a block diagram showing an example system for detecting hard-coded strings in source code. Code analyzer **603** may analyze source code **601** of application **602** to generate suspected list **604** of hard-coded strings. Specifically, code analyzer **603** may scan and parse source code **601**, generate an abstract syntax tree (**601**), and perform result filtering to create suspected list **604** of hard-coded string candidates. Details of the code analysis will be described below in more detail. Suspected list **604** may contain many hard-coded string candidates but may also contain numerous false-positives because the static code analysis alone may not be capable of distinguishing between hard-coded string literals that would eventually be exposed to the end-user via a UI and strings that are merely used internally.

Subsequently or concurrently, crawler **605** may be used to extract text from application **602** in runtime. For example, application **602** may be a web application and crawler **605** may be an automation framework (e.g., automated web browser) that crawls through all the available links to retrieve webpages and collect text from the retrieved webpages. In another example, application **602** may be a mobile or desktop application, crawler **605** may inject one or more hooks into a UI renderer within application **602** or an underlying platform (e.g., operating system) that application **602** is running on, and extract text that is displayed or otherwise presented to the end-user via a UI. Crawler **605** may ensure that every possible page, view, or interface is traversed and collected. The text strings collected by crawler **605** may be stored as valid list **606** of strings. Suspected list **604** and valid list **606** may be stored in the same database or in separate databases.

Comparing tool **607** may access suspected list **604** and valid list **606** to perform comparison and filtering. Particularly, comparison tool **607** may go through the strings contained in suspected list **604** and determine whether identical strings also exist in valid list **606**. Additional string processing may be necessary for accurate comparison. For example, any formatting operators (e.g., "% d," "% s," "% n," etc.) found in the strings in suspected list **604** may need to be taken into account when finding a match (e.g., equivalence or correspondence, but not necessarily an exact match) in valid list **606**. Any concatenation operators ("+") that are used to connect two or more strings together may also be taken in to account. More specifically, comparing tool **607** may determine that the string "Welcome, % s, to the Home Screen. Today is % s, % s % d, % d." in suspected list **604** is a match for the string "Welcome, John, to the Home Screen. Today is Tuesday, Aug. 26, 2014." found in valid list **606**. If a match is found between a string in suspected list **604** and a string in valid list **606**, the string may be regarded as a hard-coded string of interest that needs to be flagged by inclusion in filtered suspected list **608**. In other words, this hard-coded string is something that does get exposed to the end-user via the UI and therefore will need to be addressed by the developer (e.g., removed, externalized to a resource file, etc.). If no match is found for a string in suspected list **604** compared to valid list **604**, such string may be regarded as a false-positive hard-coded string (e.g., a log message, an error message, a debug message, an exception, a comment, a parameter, etc.), and may be removed or filtered out from suspected list **604**. After the comparison is completed, any remaining and unfiltered strings in suspected list **607** may be considered hard-coded strings of interest and included in filtered suspected list **608**.

Components depicted in FIG. **6** may represent separate devices, such as any number of devices described above (e.g., network nodes **103**, **105**, **107**, **109**, server **206**, terminals **240**, server **301**, etc.), or some of the components may be integrated into one or more such devices. For example, code analyzer **603** may be part of one device (e.g., a computer, a workstation, a server, a smartphone, a tablet device, etc.) while comparing tool **607** may be part of another device (e.g., a computer, a workstation, a server, a smartphone, a tablet device, etc.). Crawler **605** and application **602** may also execute on different devices from each other and/or from devices on which code analyzer **603** and comparing tool **607** are executing. Alternatively, one or more of these components may execute on the same device. Various components depicted in FIG. **6** may be implemented with hardware (e.g., a circuit, a processor, a controller, storage, etc.), software (e.g., instructions, code, a program, an application, etc.), and/or both. For example, one or more of application **602**, code analyzer **603**, crawler **605**, and comparing tool **608** may comprise instructions stored on a computer-readable storage medium and configured to be executed by a processor to perform various operations associated with their respective functions. The various operations depicted in FIG. **6** may be integrated as a phase in a continuous integration (CI) process of product development and be run automatically for each build or release. Issue reports (e.g., filtered suspected list **608**) may be generated for review by the developers after the phase.

Having disclosed some basic system components and concepts, FIGS. **7** and **9** illustrate methods that may be performed to implement various features described herein. Any of the steps disclosed herein may be performed by any of the devices or components that were heretofore described, including but not limited to network nodes **103**, **105**, **107**, **109**, server **206**, terminals **240**, server **301**, etc. The steps outlined herein are exemplary and can be implemented in any combination thereof, including combinations that exclude, add, or modify certain steps.

FIG. **7** is a flow chart for an example method of analyzing source code and generating a suspected list of hard-coded strings. In particular, the example method of claim **7** may be performed wholly or partially by code analyzer **603**, but it may also be performed wholly or partially by other devices or components heretofore described. At step **701**, code analyzer **603** may generate an abstract syntax tree (AST) based on source code **601**. Specifically, code analyzer **603** may perform code analysis on source code **601** to generate one or more ASTs. An AST may be a tree representation of the syntactic structure of source code **601**. Thus, source code **601** may be scanned and parsed to identify, through the use of the AST, various syntactic constructs (e.g., expressions, identifiers, operators, literals, etc.) and their positions within source code **601**. At step **702**, code analyzer **603** may analyze the generated AST to identify all hard-coded strings within source code **601**. At step **703**, code analyzer **603** may generate suspected list **604** based on the identified hard-coded strings from source code **601**.

Optionally, at steps **704** and **705**, code analyzer **603** may perform grammar check on the strings in suspected list **604** and filter out any false-positive results from suspected list **604**. False-positive results may be strings that were initially suspected to be hard-coded strings but later found to be not visible to the user in the end-product. Examples of false-positive results may include debug messages, error messages, log messages, exceptions, comments, parameters, and other string literals for internal use. Grammar check performed at step **704** may include a lexical analysis, a syntax analysis, a spelling check, etc. to determine whether the strings in suspected list **604** conform to the natural language rules of the target language. For example, if the target locale or target language of the application is English, then the strings in suspected list **604** may be inspected to determine if they conform to the rules of English grammar and spelling. The strings that do not pass the grammar and/or spelling test may be regarded as false-positives and discarded or filtered out from suspected list **604** because grammatically incorrect or misspelled statements are less likely to be presented to the end-user and more likely to be text for internal use. For example, strings such as “systemerror”; “c:\Windows\Program Files\MyApplication\bin\”; “appMain.cpp”; “option_print_collate”; “exception_divided_by_zero”; “Something went wrong. ErrorCode:907”; “Warning: FIX_THIS_CODE_NOW”; etc. may be identified as false-positives after failing to pass the grammar and/or spelling check. Code analyzer **603** may recognize any formatting operators, concatenation operators, and others to apply the grammar/spelling check more intelligently. For example, a formatting operator “% d” embedded in a string may not be treated as a grammatical or spelling error. Optionally, in order to increase accuracy, a human inspector may manually inspect the strings flagged by this process as potential false-positives and weed out strings that are erroneously flagged as false-negatives before they are thrown out.

FIG. **8**A illustrates an example code snippet, based on which an AST is generated. Code analyzer **603** may scan in the code, parse it into constituent elements, and generate one or more ASTs. FIG. **8**B illustrates an example AST generated based on code of FIG. **8**A. Notably, according to this example AST, the string ‘Listening on’ is identified as a literal that starts at position **76** and ends at position **91** in the line.

FIG. **9** is a flow chart for an example method of detecting hard-coded strings in source code. At step **901**, an AST may be generated based on source code of an application. At step **902**, the AST may be analyzed to identify string literals contained in the source code. Based on the identified string literals, a first list of strings is generated at step **903**. The first list of strings may be a suspected list of strings.

At step **904**, it is determined whether a string in the first list of strings passes a grammar check. If the string passes the grammar check (**904**—YES), the method proceeds to step **906**. The grammar check may determine whether the string satisfies a predetermined set of grammar and/or spelling rules. If, however, the string fails the grammar check (**904**—NO), the failed string may be removed from the first list of strings at step **905**. In other words, at least one false-positive string literals that does not satisfy predetermined grammatical criteria may be filtered out from the string literals embedded in the source code. The false-positive string literal may be a string literal used in an internal message of the application. The internal message may be a debug message, an error message, a log message, an exception, a comment, and/or a parameter.

If there are more strings in the first list of strings to perform grammar check on (**906**—YES), then the method returns to step **904** and process the next string. If the end of the first list is reached (**906**—NO), then the method proceeds to step **907**. Steps **904**, **905**, **906** related to the grammar check may be optional or performed at a different time (e.g., after step **912**).

At step **907**, strings are extracted from a UI of the application. The strings may be extracted by at least one of a crawler, an automation framework, or a hook. At step **908**, a second list of strings may be generated based on the extracted strings. In other words, the second list of strings may include strings that are rendered via a user interface of the application. The second list of strings may be a valid list of strings.

At step **909**, a comparison is made between the first list of strings and the second list of strings, and if a match is found between a string in the first list of strings and a string in the second list of strings (**909**—YES), the method proceeds to step **911**. If no match is found for the string in the first of strings relative to the second list of strings (**909**—NO), then at step **910**, the string that does not have a match in the second list of strings (e.g., false-positive result) is removed from the first list of strings. The false-positive string literal may be a string literal used in an internal message of the application. If there are more strings in the first list of strings to perform comparison on (**911**—YES), then the method returns to step **909** and process the next string in the first list of strings. However, if the end of the first list is reached (**911**—NO), then the method proceeds to step **912**, where a filtered list of strings is generated based on the first list of strings and the second list of strings. Specifically, the filtered list of strings may contain string literals that are (i) embedded in the source code of the application, and (ii) rendered via the user interface of the application. These strings identified through one or more filtering processes may be considered hard-coded strings that require removal and/or externalization from the source code and are reported to a user (e.g., a developer) for further processing. The filtered list of strings may include multiple entries, each entry including a string, a position within source code, a unique identifier, etc.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are described as example implementations of the following claims.

What is claimed is:

1. A method comprising:

generating, via a processor, a first list of strings that are embedded in source code of an application;

generating a second list of strings that are rendered via a user interface of the application;

comparing each string of the first list of strings against the second list of strings; and

generating, based on the comparison, a filtered list of strings by removing, from the first list of strings, at least one string that does not have a match in the second list of strings, wherein the filtered list of strings comprises strings that are hard-coded into the source code of the application and are rendered via the user interface of the application.

2. The method of claim **1**, wherein generating the second list of strings comprises extracting, by at least one of a crawler, an automation framework, or a hook, strings that are rendered via the user interface of the application.

3. The method of claim **1**, wherein generating the first list of strings comprises:

generating, based on the source code, an abstract syntax tree; and

analyzing the abstract syntax tree to identify the first list of strings embedded in the source code.

4. The method of claim **1**, wherein generating the first list of strings comprises filtering out, from strings embedded in the source code, at least one false-positive string that does not satisfy grammatical criteria.

5. The method of claim **1**, wherein the comparison is based on at least one of a formatting operator or a concatenation operator.

6. The method of claim **1**, wherein the generating the first list of strings comprises filtering out, from strings embedded in the source code, at least one false-positive string that is used in an internal message of the application.

7. The method of claim **6**, wherein the internal message comprises at least one of a debug message, an error message, a log message, an exception, a comment, or a parameter.

8. A system comprising:

one or more processors; and

memory storing instructions that, when executed by the one or more processors, cause the system to:

generate a first list of strings that are embedded in source code of an application;

generate a second list of strings that are rendered via a user interface of the application;

compare each string of the first list of strings against the second list of strings; and

generate, based on the comparison, a filtered list of strings by removing, from the first list of strings, at least one string that does not have a match in the second list of strings, wherein the filtered list of strings comprises strings that are hard-coded into the source code of the application and are rendered via the user interface of the application.

9. The system of claim **8**, wherein, to generate the second list of strings, the instructions, when executed by the one or more processors, further cause the system to extract, by at least one of a crawler, an automation framework, or a hook, strings that are rendered via the user interface of the application.

10. The system of claim **8**, wherein, to generate the first list of strings, the instructions, when executed by the one or more processors, further cause the system to:

generate, based on the source code, an abstract syntax tree; and

analyze the abstract syntax tree to identify the first list of strings embedded in the source code.

11. The system of claim **8**, wherein, to generate the first list of strings, the instructions, when executed by the one or more processors, further cause the system to filter out, from strings embedded in the source code, at least one false-positive string that does not satisfy grammatical criteria.

12. The system of claim **8**, wherein the comparison based on at least one of a formatting operator or a concatenation operator.

13. The system of claim **8**, wherein, to generate the first list of strings, the instructions, when executed by the one or more processors, further cause the system to filter out, from strings embedded in the source code, at least one false-positive string that is used in an internal message of the application.

14. The system of claim **13**, wherein the internal message comprises at least one of a debug message, an error message, a log message, an exception, a comment, or a parameter.

15. A non-transitory computer-readable medium storing instructions that, when executed by a computing device, cause the computing device to:

generate a first list of strings that are embedded in source code of an application;

generate a second list of strings that are rendered via a user interface of the application;

compare each string of the first list of strings against the second list of strings; and

generate, based on the comparison, a filtered list of strings by removing, from the first list of strings, at least one string that does not have a match in the second list of strings, wherein the filtered list of strings comprises strings that are hard-coded into the source code of the application and are rendered via the user interface of the application.

16. The non-transitory computer-readable medium of claim **15**, wherein, to generate the second list of strings, the instructions, when executed by the computing device, further cause the computing device to extract, by at least one of a crawler, an automation framework, or a hook, strings that are rendered via the user interface of the application.

17. The non-transitory computer-readable medium of claim **15**, wherein, to generate the first list of strings, the instructions, when executed by the computing device, further cause the computing device to:

generate, based on the source code, an abstract syntax tree; and

analyze the abstract syntax tree to identify the first list of strings embedded in the source code.

18. The non-transitory computer-readable medium of claim **15**, wherein, to generate the first list of strings, the instructions, when executed by the computing device, further cause the computing device to filter out, from strings embedded in the source code, at least one false-positive string that does not satisfy grammatical criteria.

19. The non-transitory computer-readable medium of claim **15**, wherein the comparison is based on at least one of a formatting operator or a concatenation operator.

20. The non-transitory computer-readable medium of claim **15**, wherein, to generate the first list of strings, the instructions, when executed by the computing device, further cause the computing device to filter out, from strings embedded in the source code, at least one false-positive string that is used in at least one of a debug message, an error message, a log message, an exception, a comment, or a parameter.

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